IV. CHEMICAL RELEASE AND TRANSFER PROFILE

The following is a synopsis of current scientific toxicity and fate information for the top chemicals (by weight) that facilities within this sector self-reported as released to the environment based upon 1993 TRI data. Because this section is based upon self-reported release data, it does not attempt to provide information on management practices employed by the sector to reduce the release of these chemicals. Information regarding pollutant release reductions over time may be available from EPA's TRI and 33/50 programs, or directly from the industrial trade associations that are listed in Section IX of this document. Since these descriptions are cursory, please consult the sources referenced below for a more detailed description of both the chemicals described in this section and the chemicals that appear on the full list of TRI chemicals appearing in Section IV.A.

This section is designed to provide background information on the pollutant releases that are reported by this industry. The best source of comparative pollutant release information is the Toxic Release Inventory System (TRI). Pursuant to the Emergency Planning and Community Right-to-Know Act, TRI includes self-reported facility release and transfer data for over 600 toxic chemicals. Facilities within SIC Codes 20 through 39 (manufacturing industries) that have more than 10 employees, and that are above weight-based reporting thresholds are required to report TRI on-site releases and off-site transfers. The information presented within the sector notebooks is derived from the most recently available (1993) TRI reporting year (which then included 316 chemicals), and focuses primarily on the on-site releases reported by each sector. Because TRI requires consistent reporting regardless of sector, it is an excellent tool for drawing comparisons across industries. TRI data provide the type, amount and media receptor of each chemical released or transferred.

Although this sector notebook does not present historical information regarding TRI chemical releases over time, please note that in general, toxic chemical releases have been declining. In fact, according to the 1993 Toxic Release Inventory Data Book, reported releases dropped by 43 percent between 1988 and 1993. Although on-site releases have decreased, the total amount of reported toxic waste has not declined because the amount of toxic chemicals transferred off-site has increased. Transfers have increased from 3.7 billion pounds in 1991 to 4.7 billion pounds in 1993. Better management practices have led to increases in off-site transfers of toxic chemicals for recycling. More detailed information can be obtained from EPA's annual Toxics Release Inventory Public Data Release book (which is available through the EPCRA Hotlines at 800-535-

0202), or directly from the Toxic Release Inventory System database (for user support call 202-260-1531).

Wherever possible, the sector notebooks present TRI data as the primary indicator of chemical release within each industrial category. TRI data provide the type, amount and media receptor of each chemical released or transferred. When other sources of pollutant release data have been obtained, these data have been included to augment the TRI information.

TRI Data Limitations

The reader should keep in mind the following limitations regarding TRI data. Within some sectors, the majority of facilities are not subject to TRI reporting because they are not considered manufacturing industries, or because they are below TRI reporting thresholds. Examples are the mining, dry cleaning, printing, and transportation equipment cleaning sectors. For these sectors, release information from other sources has been included.

The reader should also be aware that TRI "pounds released" data presented within the notebooks is not equivalent to a "risk" ranking for each industry. Weighting each pound of release equally does not factor in the relative toxicity of each chemical that is released. The Agency is in the process of developing an approach to assign toxicological weightings to each chemical released so that one can differentiate between pollutants with significant differences in toxicity. As a preliminary indicator of the environmental impact of the industry's most commonly released chemicals, this notebook briefly summarizes the toxicological properties of the top five chemicals (by weight) reported by the organic chemical industry.

Definitions Associated with Section IV Data Tables

General Definitions

SIC Code -- is the Standard Industrial Classification (SIC) is a statistical classification standard used for all establishment-based Federal economic statistics. The SIC codes facilitate comparisons between facility and industry data.

TRI Facilities -- are manufacturing facilities that have 10 or more full-time employees and are above established chemical throughput thresholds. Manufacturing facilities are defined as facilities in Standard Industrial Classification primary codes 20 through 39. Facilities must submit estimates for all chemicals that are on the EPA's defined list and are above throughput thresholds.

Data Table Column Heading Definitions

The following definitions are based upon standard definitions developed by EPA's Toxic Release Inventory Program. The categories below represent the possible pollutant destinations that can be reported.

RELEASES -- are an on-site discharge of a toxic chemical to the environment. This includes emissions to the air, discharges to bodies of water, releases at the facility to land, as well as contained disposal into underground injection wells.

Releases to Air (Point and Fugitive Air Emissions) -- Include all air emissions from industry activity. Point emissions occur through confined air streams as found in stacks, ducts, or pipes. Fugitive emissions include losses from equipment leaks, or evaporative losses from impoundments, spills, or leaks.

Releases to Water (Surface Water Discharges) -- encompass any releases going directly to streams, rivers, lakes, oceans, or other bodies of water. Any estimates for storm water runoff and non-point losses must also be included.

Releases to Land -- includes disposal of toxic chemicals in waste to on-site landfills, land treated or incorporation into soil, surface impoundments, spills, leaks, or waste piles. These activities must occur within the facility's boundaries for inclusion in this category.

Underground Injection -- is a contained release of a fluid into a subsurface well for the purpose of waste disposal.

TRANSFERS -- is a transfer of toxic chemicals in wastes to a facility that is geographically or physically separate from the facility reporting under TRI. The quantities reported represent a movement of the chemical away from the reporting facility. Except for off-site transfers for disposal, these quantities do not necessarily represent entry of the chemical into the environment.

Transfers to POTWs -- are waste waters transferred through pipes or sewers to a publicly owned treatments works (POTW). Treatment and chemical removal depend on the chemical's nature and treatment methods used. Chemicals not treated or destroyed by the POTW are generally released to surface waters or land filled within the sludge.

Transfers to Recycling -- are sent off-site for the purposes of regenerating or recovering still valuable materials. Once these chemicals have been recycled, they may be returned to the originating facility or sold commercially.

Transfers to Energy Recovery -- are wastes combusted off-site in industrial furnaces for energy recovery. Treatment of a chemical by incineration is not considered to be energy recovery.

Transfers to Treatment -- are wastes moved off-site for either neutralization, incineration, biological destruction, or physical separation. In some cases, the chemicals are not destroyed but prepared for further waste management.

Transfers to Disposal -- are wastes taken to another facility for disposal generally as a release to land or as an injection underground.

IV.A. EPA Toxic Release Inventory for the Organic Chemicals Industry

According to the Toxics Release Inventory (TRI) data, 417 organic chemical facilities released (to the air, water or land) and transferred (shipped off-site or discharged to sewers) a total of 438 million pounds of toxic chemicals during calendar year 1993. That represents approximately 18 percent of the 2.5 billion pounds of releases and transfers from the chemical industry as a whole (SIC 28) and about six percent of the releases and transfers for all manufacturers reporting to TRI that year. By comparison, the inorganic chemical industry's releases and transfers in 1993 totaled 249.7 million pounds, or sixty percent of the releases and transfers of the industrial organic chemical sector.

The chemical industry's releases have been declining in recent years. Between 1988 and 1992 TRI emissions from chemical companies (all those categorized within SIC 28, not just organic chemical manufacturers) to air, land, and water were reduced 44 percent, which is average for all manufacturing sectors reporting to TRI.

Because the chemical industry (SIC 28) has historically released more TRI chemicals than any other industry, the EPA has worked to improve environmental performance within this sector. This has been done through a combination of enforcement actions, regulatory requirements, pollution prevention projects, and voluntary programs (e.g. EPA's 33/50 program). In addition, the chemical industry has focused on reducing pollutant releases. For example, the Chemical Manufacturer's Association's (CMA's) Responsible Care® initiative is intended to reduce or eliminate chemical manufacturers' wastes. All 185 members of the CMA, firms that account for the majority of U.S. chemical industry sales and earnings, are required to participate in the program as a condition of CMA membership. Participation involves demonstrating a commitment to the program's mandate of continuous improvement of the environment, health, and safety. In June of 1994, the CMA approved the use of a third-party verification of management plans to meet these objectives. State-level toxics use reduction requirements, public disclosure of release and transfer information contained in TRI, and voluntary programs such as EPA's 33/50 Program have also been given as reasons for release reductions.

Exhibit 16 presents the number and volumes of chemicals released by organic chemical facilities. The quantity of the basic feedstocks released reflects their volume of usage. The inorganic chemicals among the top ten released (ammonia, nitric acid, ammonium sulfate, and sulfuric acid) are also large volume reaction feedstocks. Inorganic chemicals contained in wastes injected underground on-site account for 58 percent of the industry's releases; ammonia makes up the vast majority of TRI chemicals disposed of via underground injection. Air releases account for 40 percent (61 million pounds), and the remaining approximately 1.5 percent (2.4 million pounds) is discharged directly to water or land disposed.

Exhibit 17 presents the number and volumes of chemicals transferred by organic chemical facilities. Off-site transfers account for the largest amount, 65 percent, of the organic chemical industry's total releases and transfers as reported in TRI. Three chemicals (sulfuric acid, methanol and *tert*-butyl alcohol) account for over one-half of the 287 million pounds transferred off-site. The 49 million pounds of POTW discharges (primarily methanol and ammonia) account for 17 percent of releases and transfers.

The frequency with which chemicals are reported by facilities within a sector is one indication of the diversity of operations and processes. Many chemicals are released or transferred by a small number of facilities, which indicates a wide diversity of production processes, particularly for specialty organic chemicals -- over one half of the 204 chemicals reported are released by fewer than 10 facilities. However, the organic chemical industry is also characterized by one of the largest numbers of chemicals reported by any manufacturing sector. Of the over 300 chemicals currently listed on TRI, 204 are reported as released or transferred by at least one organic chemical facility.

Exhibit 16: 1993 Releases for Organic Chemical Manufacturing Facilities in TRI, by Number of Facilities Reporting
(Releases reported in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	FUGITIVE AIR	POINT AIR	WATER DISCHARGES	UNDERGROUND INJECTION	LAND DISPOSAL	TOTAL RELEASES	AVG. RELEASE PER FACILITY
SULFURIC ACID	216	38,135	84,847	50	5,590,786	6,367	5,720,185	26,482
METHANOL	194	3,872,663	5,125,135	60,131	5,944,874	6,212	15,009,015	77,366
HYDROCHLORIC ACID	144	389,413	1,153,510	29,028	82,677	974	1,655,602	11,497
AMMONIA	116	1,111,918	2,572,704	726,248	28,145,563	235,994	32,792,427	282,693
TOLUENE	109	851,359	957,684	154	194,937	1,019	2,005,153	18,396
XYLENE (MIXED ISOMERS)	89	730,696	207,630	334	161,156	313	1,100,129	12,361
ETHYLENE GLYCOL	86	204,427	3,272,040	28,445	5,867,002	63,735	9,435,649	109,717
CHLORINE	85	130,761	157,695	2,236	780	0	291,472	3,429
ACETONE	84	5,159,656	1,348,278	4,040	1,264,031	7,195	7,783,200	92,657
FORMALDEHYDE	78	280,006	382,300	4,610	75,086	1,205	743,207	9,528
BENZENE	72	850,106	803,898	494	231,093	308	1,885,899	26,193
GLYCOL ETHERS	67	136,339	22,304	23,684	88	8,197	190,612	2,845
PHOSPHORIC ACID	67	11,835	1,378	15	0	5	13,233	198
PHENOL	62	434,770	268,529	3,620	2,011,015	1,134	2,719,068	43,856
N-BUTYL ALCOHOL	56	256,456	236,442	15,550	1,363,944	1,303	1,873,695	33,459
STYRENE	47	210,666	277,926	283	132,575	851	622,301	13,240
ZINC COMPOUNDS	46	9,364	15,103	8,011	9,254	36,160	77,892	1,693
COPPER COMPOUNDS	44	1,274	1,363	6,454	147,134	33,141	189,366	4,304
NAPHTHALENE	44	305,328	337,758	45	63,265	12,131	718,527	16,330
ETHYLBENZENE	42	230,216	138,969	60	333,489	102	702,836	16,734
ETHYLENE	38	2,649,664	4,027,122	0	0	0	6,676,786	175,705
MALEIC ANHYDRIDE	38	17,956	20,838	15	0	0	38,809	1,021
DICHLOROMETHANE	36	65,419	191,239	600	0	0	257,258	7,146
PROPYLENE	35	2,353,950	602,285	0	0	0	2,956,235	84,464
ACRYLIC ACID	31	269,020	108,887	14	160,000	0	537,921	17,352
BIPHENYL	28	51,616	10,857	10	44,266	6,138	112,887	4,032
CYCLOHEXANE	28	232,868	812,798	17,370	258,817	169	1,322,022	47,215
DIETHANOLAMINE	28	33,271	1,035	22,766	0	53,663	110,735	3,955
BARIUM COMPOUNDS	27	6,838	4,156	6,900	1,600	22	19,516	723
METHYL ETHYL KETONE	27	166,230	215,714	290	246,072	0	628,306	23,271
NITRIC ACID	27	3,949	26,784	2,000	16,097,146	2,490	16,132,369	597,495
PHTHALIC ANHYDRIDE	27	33,350	13,593	0	0	0	46,943	1,739
ANILINE	26	73,410	54,142	2,073	430,763	20	560,408	21,554
CHLOROMETHANE	25	263,303	719,728	570	0	0	983,601	39,344
CUMENE	25	299,630	436,635	40	17,000	200	753,505	30,140
CHROMIUM COMPOUNDS	24	725	1,239	1,365	3,269	6,184	12,782	533
ETHYLENE OXIDE	24	130,124	70,116	2,359	28,000	895	231,494	9,646
PROPYLENE OXIDE	23	175,006	129,503	5,472	5,151	6,125	321,257	13,968
1,3-BUTADIENE	23	496,952	196,341	1,321	0	284	694,898	30,213
1,2,4-TRIMETHYLBENZENE	22	12,418	6,232	286	304	25	19,265	876
ACETALDEHYDE	20	150,111	1,131,895	1,436	1,346,120	16	2,629,578	131,479
METHYL ISOBUTYL KETONE	19	1,632,377	298,258	6,119	0	5	1,936,759	101,935
NICKEL COMPOUNDS	19	758	2,294	2,251	100,816	4,113	110,232	5,802
ACRYLONITRILE	18	27,146	38,612	17	629,590	10	695,375	38,632
CHLOROETHANE	18	32,455	54,124	2,179	0	0	88,758	4,931
ANTHRACENE	17	6,817	9,620	10	0	5,119	21,566	1,269
CHLOROBENZENE	16	47,007	23,124	272	51,000	293	121,696	7,606
1,1,1-TRICHLOROETHANE	16	26,046	12,350	0	0	0	38,396	2,400
CRESOL (MIXED ISOMERS)	15	72,079	17,910	35	793,402	120	883,546	58,903
DICHLORODIFLUOROMETHANE	15	389,258	73,271	10	1	100	462,640	30,843
TERT-BUTYL ALCOHOL	15	1,068,315	234,114	158,120	302,943	180	1,763,672	117,578
AMMONIUM SULFATE	14	10	6,810	122	5,746,409	420,001	6,173,352	440,954

Exhibit 16 (cont.): 1993 Releases for Organic Chemical Manufacturing Facilities in TRI, by Number of Facilities Reporting
(Releases reported in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	FUGITIVE AIR	POINT AIR	WATER DISCHARGES	UNDERGROUND INJECTION	LAND DISPOSAL	TOTAL RELEASES	AVG. RELEASES PER FACILITY
DIMETHYL SULFATE	14	1,310	644	0	0	5	1,959	140
TETRACHLOROETHYLENE	14	29,594	17,654	29	0	0	47,277	3,377
CREOSOTE	13	55,110	74,595	5	0	585	130,295	10,023
BUTYL ACRYLATE	12	81,815	45,684	306	0	0	127,805	10,650
CARBON DISULFIDE	12	43,576	10,221	251	0	0	54,048	4,504
EPICHLOROHYDRIN	12	17,289	2,296	292	0	0	19,877	1,656
O-XYLENE	12	102,254	160,275	141	0	0	262,670	21,889
1,2-DICHLOROETHANE	12	220,032	968,026	70	0	0	1,188,128	99,011
BENZOYL CHLORIDE	11	6,087	1,819	0	0	5	7,911	719
BUTYRALDEHYDE	11	34,477	31,689	7	189,447	0	255,620	23,238
CHLOROFORM	11	12,764	62,055	693	74	200	75,786	6,890
COBALT COMPOUNDS	11	0	4,592	80,304	0	18,696	103,592	9,417
DIBENZOFURAN	11	10,880	10,059	10	0	910	21,859	1,987
DIETHYL SULFATE	11	616	17	0	0	5	638	58
ETHYL ACRYLATE	11	46,571	35,631	410	2,400	0	85,012	7,728
HYDROQUINONE	11	188	5	30	190,000	117	190,340	17,304
MANGANESE COMPOUNDS	11	1,760	28,017	131,505	0	61,000	222,282	20,207
METHYL ACRYLATE	11	51,940	49,500	5	0	0	101,445	9,222
METHYL METHACRYLATE	11	76,114	119,538	750	0	250	196,652	17,877
METHYL TERT-BUTYL ETHER	11	143,917	70,795	85	8,772	0	223,569	20,324
TRICHLOROETHYLENE	11	42,619	936	5	0	0	43,560	3,960
VINYL ACETATE	11	166,157	744,939	0	892,698	0	1,803,794	163,981
BENZYL CHLORIDE	10	2,297	432	0	0	58	2,787	279
HYDROGEN CYANIDE	10	10,539	298,141	0	651,815	12	960,507	96,051
M-CRESOL	10	20,937	2,442	406	520,000	0	543,785	54,379
QUINOLINE	10	3,327	17,900	40	63,000	190	84,457	8,446
SEC-BUTYL ALCOHOL	10	15,241	8,310	2,440	0	5	25,996	2,600
ACETONITRILE	9	79,850	64,366	217	3,969,793	13	4,114,239	457,138
ACRYLAMIDE	9	16,503	1,597	0	930,000	160	948,260	105,362
CARBON TETRACHLORIDE	9	55,191	55,130	234	63	0	110,618	12,291
FREON 113	9	23,242	84,780	44	4	406	108,476	12,053
HYDRAZINE	9	7,195	1,551	0	0	0	8,746	972
TRICHLOROFLUOROMETHAN	9	103,857	74,459	50	11	750	179,127	19,903
ALLYL ALCOHOL	8	36,773	6,928	5,100	192,966	0	241,767	30,221
CHLOROACETIC ACID	8	3,786	413	5	0	0	4,204	526
COPPER	8	0	170	1,329	0	4,880	6,379	797
CUMENE HYDROPEROXIDE	8	11,380	5,404	190	380,000	3	396,977	49,622
CYANIDE COMPOUNDS	8	26,142	1,543	7,391	426,890	2,846	464,812	58,102
ISOBUTYRALDEHYDE	8	37,012	16,187	255	34,783	0	88,237	11,030
O-TOLUIDINE	8	8,370	155	5	9,600	7	18,137	2,267
P-CRESOL	8	13,522	2,197	273	260,000	0	275,992	34,499
PROPIONALDEHYDE	8	20,845	13,991	5	31,995	0	66,836	8,355
2-METHOXYETHANOL	8	27,431	3,436	430	0	0	31,297	3,912
4,4'-	8	67,835	8,979	337	43,000	250	120,401	15,050
DI(2-ETHYLHEXYL)	7	270	255	0	0	0	525	75
DIBUTYL PHTHALATE	7	271	505	23	0	0	799	114
DIMETHYL PHTHALATE	7	5,424	1,461	12	1,300	5	8,202	1,172
HYDROGEN FLUORIDE	7	3,894	4,627	0	1	0	8,522	1,217
NICKEL	7	6	250	5	0	113	374	53
PHOSGENE	7	265	293	0	0	0	558	80

Exhibit 16 (cont.): 1993 Releases for Organic Chemical Manufacturing Facilities in TRI, by Number of Facilities Reporting
(Releases reported in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	FUGITIVE AIR	POINT AIR	WATER DISCHARGES	UNDERGROUND INJECTION	LAND DISPOSAL	TOTAL RELEASES	AVG. RELEASES PER FACILITY
ANTIMONY COMPOUNDS	6	20	257	125	759	10	1,171	195
BIS(2-ETHYLHEXYL) ADIPATE	6	23	257	0	0	0	280	47
LEAD COMPOUNDS	6	304	256	1	0	0	561	94
M-XYLENE	6	90,153	51,519	0	0	0	141,672	23,612
N,N-DIMETHYLANILINE	6	906	2,745	250	0	0	3,901	650
P-XYLENE	6	240,522	2,362,739	1	0	1	2,603,263	433,877
1,2,4-TRICHLOROBENZENE	6	2,536	38,272	10	0	0	40,818	6,803
AMMONIUM NITRATE (SOLUTION)	5	0	750	8,500	0	0	9,250	1,850
CADMIUM COMPOUNDS	5	1,895	1,005	0	0	0	2,900	580
DIETHYL PHTHALATE	5	510	10	0	0	250	770	154
MOLYBDENUM TRIOXIDE	5	0	7,100	0	55,000	99	62,199	12,440
O-ANISIDINE	5	405	11	81	0	116	613	123
P-CRESIDINE	5	285	125	5	0	85	500	100
VINYL CHLORIDE	5	31,082	3,504	0	0	0	34,586	6,917
ALLYL CHLORIDE	4	2,702	294	0	0	0	2,996	749
BENZOYL PEROXIDE	4	250	977	0	0	0	1,227	307
BUTYL BENZYL PHTHALATE	4	18	0	0	83	7	108	27
CHROMIUM	4	0	0	250	0	1	251	63
METHYLENEBIS (PHENYLISOCYANATE)	4	3,053	256	0	0	5	3,314	829
O-CRESOL	4	8,804	1,087	95	560,000	0	569,986	142,497
1,1,2-TRICHLOROETHANE	4	2,672	90	3	0	0	2,765	691
1,2-DICHLOROETHYLENE	4	224	50	0	0	0	274	69
1,4-DIOXANE	4	15,613	2,414	21,715	0	2,100	41,842	10,461
2-ETHOXYETHANOL	4	26,298	10,122	1,932	0	0	38,352	9,588
3,3'-DICHLOROBENZIDINE	4	0	0	0	0	0	0	0
4,6-DINITRO-O-CRESOL	4	6	37	10	0	0	53	13
ASBESTOS (FRIABLE)	3	0	0	0	0	0	0	0
DIAMINOTOLUENE (MIXED	3	1,205	19	500	0	10	1,734	578
DICHLOROTETRAFLUOROETHANE	3	7,967	23,440	0	0	0	31,407	10,469
ISOPROPYL ALCOHOL	3	157	34	0	0	0	191	64
NITROBENZENE	3	11,255	1,030	0	0	0	12,285	4,095
PICRIC ACID	3	2	2	1	38,294	1	38,300	12,767
SILVER	3	0	9	62	210	0	281	94
SILVER COMPOUNDS	3	3,743	0	0	0	0	3,743	1,248
STYRENE OXIDE	3	298	38	0	0	0	336	112
VINYLIDENE CHLORIDE	3	162	158	0	0	0	320	107
1,1,2,2-TETRACHLOROETHANE	3	141	10	0	0	0	151	50
1,2-DICHLOROBENZENE	3	7,605	8,412	1	0	0	16,018	5,339
2-NITROPHENOL	3	5	10	5	0	0	20	7
2,4-DIAMINOTOLUENE	3	13	0	0	0	0	13	4
ANTIMONY	2	260	33	0	0	0	293	147
BROMOMETHANE	2	2,300	618,500	0	0	0	620,800	310,400
C.I. BASIC GREEN 4	2	0	0	0	0	0	0	0
C.I.FOOD RED 15	2	0	1	0	0	0	1	1
CHLOROPRENE	2	6	13	0	0	0	19	10
DICHLOROBENZENE (MIXED	2	219	13	0	1	0	233	117

Exhibit 16 (cont.): 1993 Releases for Organic Chemical Manufacturing Facilities in TRI, by Number of Facilities Reporting
(Releases reported in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	FUGITIVE AIR	POINT AIR	WATER DISCHARGES	UNDERGROUND INJECTION	LAND DISPOSAL	TOTAL RELEASES	AVG. RELEASES PER FACILITY
TOLUENEDIISOCYANATE	2	5	5	0	0	250	260	13,059
(MIXED ISOMERS)	0			0	0	0		
1,2-BUTYLENE OXIDE	2	289	0	0	0	0	289	145
2,4-DIMETHYLPHENOL	0	3,400	160	80	0	0	58,640	29,320
2,3-DINITROPHENOL	2	1	2	110	0	0	117	59
3,3'-DIMETHOXYBENZIDINE	0	0	0	4	0	0	4	2
4,4'-METHYLENEDIANILINE	(1)	2,404	5	0	150	0	2,559	1,280
ACETAMIDE	0	2	8	0	89,000	0	89,010	89,010
ALPHA-NAPHTHYLAMINE	0	0	0	0	0	0	0	0
ALUMINUM (FUME OR DUST)	1	115	0	219	0	0	334	334
BENZIOIC TRICHLORIDE	1	1,318	5	0	0	0	1,323	1,323
BIS(2-CHLOROETHYL) ETHER	1	22	0	0	0	0	22	22
BROMOCHLORODIFLUOROMETHANE	1	0	0	0	0	0	0	0
C.I. BASIC RED 1	1	0	0	0	0	0	0	0
C.I. DISPERSE YELLOW 3	1	399	0	28	0	9,199	9,626	9,626
C.I. SOLVENT YELLOW 3	1	0	0	0	0	0	0	0
CADMIUM	1	0	0	0	0	0	0	0
CHLORDANE	1	51	0	15	0	0	66	66
COBALT	1	0	1,800	460	0	1,600	3,860	3,860
CUPFERRON	1	2	23	0	0	0	25	25
ETHYL CHLOROFORMATE	1	250	5	0	0	0	255	255
ETHYLENE THIOUREA	1	5	5	0	0	0	10	10
ETHYLENEIMINE	1	0	0	0	0	0	0	0
HEPTACHLOR	1	31	0	2	0	0	33	33
HEXACHLOROCYCLOPENTADIENE	1	1,342	861	0	0	0	2,203	2,203
HEXACHLOROETHANE	1	1	0	0	0	0	1	1
HYDRAZINE SULFATE	1	0	0	0	0	0	0	0
LEAD	1	5	5	0	0	0	10	10
M-DINITROBENZINE	1	49	7	0	0	0	56	56
METHYL IODIDE	1	6,800	92	0	0	0	6,892	6,892
METHYL ISOCYANATE	1	0	0	0	0	0	0	0
METHYLENE BROMIDE	1	3	13	0	0	0	16	16
O-DINITROBENZENE	1	1	1	0	0	0	2	2
OXY-ALKYLATED ALCOHOL	1	250	5	0	0	0	255	255
P-PHENYLENEDIAMINE	1	1	1	0	0	0	4	4
PHENYL MIXTURE	1	2,600	200	0	0	0	2,800	2,800
PHOSPHORUS (YELLOW OR WHITE)	1	0	0	0	0	0	0	0
SACCHARIN (MANUFACTURING)	1	50	1	0	0	0	51	51
TITANIUM TETRACHLORIDE	1	0	0	0	0	0	0	0
ZINC (FUME OR DUST)	1	0	290	0	0	0	290	290
1,3-DICHLOROBENZENE	1	0	0	0	0	0	0	0
1,3-DICHLOROPROPYLENE	1	3	22	0	0	0	25	25
1,4-DICHLOROBENZENE	1	32	95	0	0	0	127	127
2-NITROPROPANE	1	0	0	0	0	0	0	0
2,4-DIAMINOANISOLE	1	0	13	0	0	0	13	13
2,4-DINITROTOLUENE	1	1	2	0	0	0	3	3
2,6-SYLIDINE	1	53	2	0	0	0	55	55
4-NITROPHENOL	1	290	21	0	0	0	311	311
5-NITRO-O-ANISIDINE	1	5	5	0	0	0	10	10

Exhibit 17: 1993 Transfers for Organic Chemical Manufacturing Facilities in TRI, by Number of Facilities Reporting (Transfers reported in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	POTW DISCHARGES	DISPOSAL	RECYCLING	TREATMENT	ENERGY RECOVERY	TOTAL TRANSFERS	AVG. TRANSFERS PER FACILITY
SULFURIC ACID	216	60,857	1,460,275	84,722,700	3,530,520	0	86,596,884	400,912
METHANOL	194	210,007,643	298,453	5,596,077	4,597,065	11,815,643	43,307,981	223,237
HYDROCHLORIC ACID	144	742,576	770,703	7,415	2,680,884	182	4,202,346	29,183
AMMONIA	116	8,351,095	1,263,566	162,738	83,271	930	9,861,610	85,014
TOLUENE	109	13,790	267,107	7,155,414	999,051	9,256,100	17,691,462	162,307
XYLENE (MIXED ISOMERS)	89	19,513	248,470	303,172	205,720	4,912,122	5,688,997	63,921
ETHYLENE GLYCOL	86	2,630,290	291,143	122,260	2,504,914	4,915,874	10,464,481	121,680
CHLORINE	85	30,671	22	0	115,400	2,687	148,780	1,750
ACETONE	84	2,452,706	27,530	182,320	859,366	3,893,746	7,415,668	88,282
FORMALDEHYDE	78	264,163	403	173	102,654	1,055	368,448	4,724
BENZENE	72	596	31,498	705,846	225,803	174,445	1,138,188	158,808
GLYCOL ETHERS	67	2,469,069	82,646	10,170	173,874	254,182	2,989,941	44,626
PHOSPHORIC ACID	67	36,422	11,680	0	2,166	15	50,283	750
PHENOL	62	559,856	96,193	3,300	247,644	466,822	1,373,815	22,158
N-BUTYL ALCOHOL	56	235,678	193,040	210	335,171	2,024,030	2,788,129	49,788
STYRENE	47	9,772	12,738	9,935	714,896	250,703	998,044	21,235
ZINC COMPOUNDS	46	53,120	1,078,844	173,261	62,751	16,914	1,384,890	30,106
COPPER COMPOUNDS	44	46,957	242,892	1,458,665	187,352	0	193,866	43,997
NAPHTHALENE	44	3,853	156,104	56,080	218,493	220,473	655,003	14,886
ETHYLBENZENE	42	331	28,706	4,765	12,484	448,357	494,643	11,777
ETHYLENE	38	0	68	0	0	0	68	2
MALEIC ANHYDRIDE	38	155	7,797	0	2,563	0	10,515	277
DICHLOROMETHANE	36	533	814	539,664	278,008	420,139	1,239,158	34,421
PROPYLENE	35	0	0	0	380,000	0	380,000	10,857
ACRYLIC ACID	31	29,470	26,822	0	73,140	7,855,500	7,984,932	257,578
BIPHENYL	28	265,741	9,922	14,409	92,951	75,951	458,974	16,392
CYCLOHEXANE	28	3,083	1,420	1,034,820	196,873	406,927	1,643,123	58,683
DIETHANOLAMINE	28	123,941	46,624	0	1,428	6,839	178,832	6,387
BARIUM COMPOUNDS	27	80,991	251,349	1,039	22,895	32,435	388,709	14,397
METHYL ETHYL KETONE	27	88,200	14,967	7,402	34,173	1,703,103	1,847,845	68,439
NITRIC ACID	27	355	232,000	0	7,160	0	239,515	8,871
PHTHALIC ANHYDRIDE	27	3,956	46,965	0	34,579	1,774,375	1,859,875	68,884
ANILINE	26	1,309,605	390,621	0	28,201	166,308	1,894,735	72,874
CHLOROMETHANE	25	788	6	0	91,521	47,285	139,600	5,584
CUMENE	25	20,017	5,761	4,511	8,372	68,031	106,692	4,268
CHROMIUM COMPOUNDS	24	4,982	44,909	561,231	110,976	190	722,288	30,095
ETHYLENE OXIDE	24	18,441	1,989	0	0	1	20,431	851
PROPYLENE OXIDE	23	9,409	9,564	0	7	2,660	21,640	941
1,3-BUTADIENE	23	250	550	0	21	81	902	39
1,2,4-TRIMETHYLBENZENE	22	49,994	5,068	4,511	451	60,471	120,495	5,477
ACETALDEHYDE	20	80,071	0	0	264	0	80,335	4,019
METHYL ISOBUTYL KETONE	19	50,988	642	25	856	289,105	341,616	17,980
NICKEL COMPOUNDS	19	5,504	43,454	747,998	211,744	0	1,008,700	53,089
ACRYLONITRILE	18	35,489	0	0	349,878	585,483	970,850	53,936
CHLOROETHANE	18	5	0	151,000	388,895	0	539,900	29,994
ANTHRACENE	17	256	28,683	8,909	2,600	53,834	94,282	5,546
CHLOROBENZENE	16	1,076	915	157	17,904	15,591	35,643	2,228
1,1,1-TRICHLOROETHANE	16	12	0	16,461	620,387	1,591	638,451	39,903
CRESOL (MIXED ISOMERS)	15	250	4,113	6,500	26,725	447	38,035	2,536
DICHLORODIFLUOROMETHANE	15	8	8	0	0	0	16	1
TERT-BUTYL ALCOHOL	15	862,730	255,223	5,324	328,262	29,383,823	30,835,362	2,055,691
AMMONIUM SULFATE	14	5,178,324	250	0	211,000	0	5,389,574	384,970

Exhibit 17(cont.): 1993 Transfers for Organic Chemical Manufacturing Facilities in TRI, by Number of Facilities Reporting
(Transfers reported in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	POTW DISCHARGES	DISPOSAL	RECYCLING	TREATMENT	ENERGY RECOVERY	TOTAL TRANSFERS	AVG. TRANSFERS PER FACILITY
DIMETHYL SULFATE	14	255	0	39,542	0	0	39,797	2,843
TETRACHLOROETHYLENE	14	447	79	1,126	282,805	11,855	296,312	21,165
CREOSOTE	13	0	700,472	273,000	300	29,220	1,002,992	77,153
BUTYL ACRYLATE	12	279	725	0	7,541	0	8,545	712
CARBON DISULFIDE	12	7,289	279	4,413	7,925	125,206	145,112	12,093
EPICHLOROHYDRIN	12	255	0	0	185	0	440	37
O-XYLENE	12	28	28,557	5,414	10,341	861,637	905,977	75,498
1,2-DICHLOROETHANE	12	731	54,402	1,700,000	402,888	406	2,158,427	179,869
BENZOYL CHLORIDE	11	0	250	0	0	0	250	23
BUTYRALDEHYDE	11	0	1,700	450	0	1,700	3,850	350
CHLOROFORM	11	264	0	3,100	131,685	19,297	154,346	14,031
COBALT COMPOUNDS	11	14	184,500	148,400	7	0	332,921	30,266
DIBENZOFURAN	11	250	25,701	3,609	0	19,988	49,548	4,504
DIETHYL SULFATE	11	10	0	5,370,000	0	0	53,701,010	488,183
ETHYL ACRYLATE	11	500	6,950	0	187,311	1,378,573	1,573,334	143,030
HYDROQUINONE	11	1,210	32,261	0	338	0	33,809	3,074
MANGANESE COMPOUNDS	11	5,019	819,758	11,600	0	0	836,377	76,034
METHYL ACRYLATE	11	2,110	250	0	5,765	10,508	18,633	1,694
METHYL METHACRYLATE	11	563	750	71,000	226,520	10,410	309,243	28,113
METHYL TERT-BUTYL ETHER	11	31	133,320	0	0	237,779	371,130	33,739
TRICHLOROETHYLENE	11	7	0	1,143	310,803	0	311,953	28,359
VINYL ACETATE	11	95,453	390	0	9,341	561,083	666,267	60,570
BENZYL CHLORIDE	10	250	0	0	14	30,980	31,244	3,124
HYDROGEN CYANIDE	10	250	2,053	0	74	250	2,627	263
M-CRESOL	10	9,649	13,336	270,000	51,118	2,923	347,026	34,703
QUINOLINE	10	250	5,482	3,609	2	5,354	14,397	1,470
SEC-BUTYL ALCOHOL	10	2,046	145,000	0	1,682	4,082,657	4,231,385	423,139
ACETONITRILE	9	255	1,601	0	410	263,316	265,582	29,509
ACRYLAMIDE	9	79,559	500	0	20,470	44,330	154,859	17,207
CARBON TETRACHLORIDE	9	1,604	1,366	1,750	136,570	0	141,290	15,699
FREON 113	9	0	12	13,215	64,636	0	77,863	8,651
HYDRAZINE	9	1,400	3,617	0	0	0	5,017	557
TRICHLOROFLUOROMETHANE	9	349	0	750	2,433	0	3,532	392
ALLYL ALCOHOL	8	27,663	4,271	0	28,172	139,592	199,698	24,962
CHLOROACETIC ACID	8	0	250	0	1,026	150	1,426	178
COPPER	8	0	30,937	35,708	21,000	0	86,756	10,845
CUMENE HYDROPEROXIDE	8	0	415	0	3,566	0	3,981	498
CYANIDE COMPOUNDS	8	3,005	3,231	0	3,292	0	9,528	1,191
ISOBUTYRALDEHYDE	8	0	0	200	32,000	655,579	687,779	85,972
O-TOLUIDINE	8	5,819	42	0	0	220	6,081	760
P-CRESOL	8	866,495	7,086	160,000	10,886	41,466	1,085,933	135,742
PROPIONALDEHYDE	8	0	3,167	0	0	0	3,167	396
2-METHOXYETHANOL	8	46,000	16,300	70	0	91,736	154,106	19,263
4,4'-ISOPROPYLIDENEDIPHENOL	8	255	30,767	0	1,231	5,447	37,700	4,713
DI(2-ETHYLHEXYL)	7	10	250	0	250	1,424	1,934	276
DIBUTYL PHTHALATE	7	256	296	0	658	5,659	6,869	981
DIMETHYL PHTHALATE	7	119,565	825	0	3,967	618	124,975	17,854
HYDROGEN FLUORIDE	7	0	1	0	3,603	0	3,604	515
NICKEL	7	748	3,413	192,295	0	0	196,456	28,065
PHOSGENE	7	0	0	0	0	0	0	0

Exhibit 17(cont.): 1993 Transfers for Organic Chemical Manufacturing Facilities in TRI, by Number of Facilities Reporting
(Transfers reported in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	POTW DISCHARGES	DISPOSAL	RECYCLING	TREATMENT	ENERGY RECOVERY	TOTAL TRANSFERS	AVG. TRANSFER PER FACILITY
ANTIMONY COMPOUNDS	6	124	2,152	0	2,450	22,055	27,031	4,505
BIS(2-ETHYLHEXYL) ADIPATE	6	250	746	0	5	308	1,309	218
LEAD COMPOUNDS	6	2	53,692	0	213	0	53,907	8,985
M-XYLENE	6	0	237	17,143	794	884	19,058	3,176
N,N-DIMETHYLANILINE	6	52,126	0	0	1,500	120,000	173,626	28,938
P-XYLENE	6	0	1,058	0	5,260	1,402	7,720	1,287
1,2,4-TRICHLOROBENZENE	6	503	3,255	520	5,428	4,400	14,106	2,351
AMMONIUM NITRATE (SOLUTION)	5	28,800	2,530,000	0	0	0	2,558,800	511,760
CADMIUM COMPOUNDS	5	29	21,776	0	3,738	1,128	26,671	5,334
DIETHYL PHTHALATE	5	255	94	0	500	250	1,099	220
MOLYBDENUM TRIOXIDE	5	0	1,897	17,000	19,000	0	37,897	7,579
O-ANISIDINE	5	0	0	0	0	0	0	0
P-CRESIDINE	5	28,223	0	0	1,400	0	29,623	5,925
VINYL CHLORIDE	5	0	1	53,000	1,329	0	54,330	10,866
ALLYL CHLORIDE	4	0	0	0	0	0	0	0
BENZOYL PEROXIDE	4	9,980	0	0	4,620	0	14,600	3,650
BUTYL BENZYL PHTHALATE	4	158	43	0	12,943	0	13,144	3,286
CHROMIUM	4	0	0	0	21,505	0	21,505	5,376
METHYLENEBIS	4	0	0	0	13,270	0	13,270	3,318
(PHENYLISOCYANATE)					11,109	1,301	59,061	14,765
O-CRESOL	4	40,541	6,110	0				
1,1,2-TRICHLOROETHANE	4	0	70	57,000	236,101	0	293,171	73,298
1,2-DICHLOROETHYLENE	4	0	0	2,100	10	0	21,110	528
1,4-DIOXANE	4	0	0	8	0	0	8	2
2-ETHOXYETHANOL	4	390,022	0	328,374	11,783	150,875	881,054	220,264
3,3'-DICHLOROBENZIDINE	4	10	5	0	250	0	265	66
4,6-DINITRO-O-CRESOL	4	0	6,630	0	4,422	1,376	12,428	3,107
ASBESTOS (FRIABLE)	3	0	28,894	0	0	0	28,894	9,631
DIAMINOTOLUENE (MIXED ISOMERS)	3	550	0	0	172	1,100	1,822	607
DICHLOROTETRAFLUOROETHANE	3	0	15	0	51	0	66	22
ISOPROPYL ALCOHOL	3	0	0	50	81,000	72,700	153,750	51,250
NITROBENZENE	3	108	420	0	8,620	5,440	14,588	4,863
PICRIC ACID	3	0	0	0	0	0	0	0
SILVER	3	0	590	35,000	0	0	35,590	11,863
SILVER COMPOUNDS	3	0	0	48,230	0	0	48,230	16,077
STYRENE OXIDE	3	0	0	0	0	0	0	0
VINYLIDENE CHLORIDE	3	169	0	0	10,519	0	40,688	13,563
1,1,2,2-TETRACHLOROETHANE	3	0	17	1	10	0	28	9
1,2-DICHLOROBENZENE	3	0	0	860	1,477	12,830	15,167	5,056
2-NITROPHENOL	3	0	0	0	4,216	4,592	8,808	2,936
2,4-DIAMINOTOLUENE	3	0	0	0	882	0	882	294
ANTIMONY	2	8,355	7,657	58,716	0	0	74,728	37,364
BROMOMETHANE	2	0	0	0	0	0	0	0
C.I. BASIC GREEN 4	2	83	0	0	0	0	83	42
C.I.FOOD RED 15	2	1,100	0	0	0	0	1,100	550
CHLOROPRENE	2	0	0	134,800	570	0	135,370	67,685
DICHLOROBENZENE (MIXED	2	0	0	0	0	128	128	64
HEXACHLORO-1,3-BUTADIENE	2	0	0	0	13,750	0	13,750	6,875
HEXACHLOROBENZENE	2	0	0	1	2,503	0	2,504	1,252
MONOCHLOROPENTAFLUOROEHTANE	2	0	0	0	0	0	0	0

Exhibit 17(cont.): 1993 Transfers for Organic Chemical Manufacturing Facilities in TRI, by Number of Facilities Reporting
(Transfers reported in pounds/year)

CHEMICAL NAME	# REPORTING CHEMICAL	POTW DISCHARGES	DISPOSAL	RECYCLING	TREATMENT	ENERGY RECOVERY	TOTAL TRANSFERS	AVG. TRANSFER PER FACILITY
TOLUENEDIISOCYANATE (MIXED ISOMERS)	2	0	0	0	9,050	2,700	11,750	5,875
1,2-BUTYLENE OXIDE	2	0	0	0	0	373,200	373,200	186,600
2,4-DIMETHYLPHENOL	2	0	0	0	13,000	0	17,244	8,622
2,3-DINITROPHENOL	2	0	0	0	9,000	0	9,020	4,510
3,3'-DIMETHOXYBENZIDINE	2	0	635	3,609	0	0	0	0
4,4'-METHYLENEDIANILINE	2	960	20	0	0	2,530	3,490	1,745
ACETAMIDE	1	0	0	0	98	0	98	98
ALPHA-NAPHTHYLAMINE	1	0	0	0	0	0	0	0
ALUMINUM (FUME OR DUST)	1	0	0	0	0	0	0	0
BENZIOIC TRICHLORIDE	1	0	0	0	0	0	0	0
BIS(2-CHLOROETHYL) ETHER	1	0	0	0	0	0	0	0
BROMOCHLORODIFLUOROMETHANE	1	0	0	0	0	0	0	0
C.I. BASIC RED 1	1	24	0	0	0	0	24	24
C.I. DISPERSE YELLOW 3	1	0	1,658	0	0	0	1,658	1,658
C.I. SOLVENT YELLOW 3	1	0	0	0	0	0	0	0
CADMIUM	1	0	0	0	0	0	0	0
CHLORDANE	1	51	0	0	11	0	62	62
COBALT	1	0	21	0	0	0	21	21
CUPFERRON	1	0	0	0	2,300	0	2,300	2,300
ETHYL CHLOROFORMATE	1	0	0	0	0	0	0	0
ETHYLENE THIOUREA	1	0	250	0	0	0	250	250
ETHYLENEIMINE	1	0	0	0	0	0	0	0
HEPTACHLOR	1	42	0	0	77,287	0	77,329	77,329
HEXACHLOROCYCLOPENTADIENE	1	636	0	0	4,810	0	5,446	5,446
HEXACHLOROETHANE	1	0	0	0	0	0	0	0
HYDRAZINE SULFATE	1	0	0	0	0	0	0	0
LEAD	1	0	0	0	0	0	0	0
M-DINITROBENZINE	1	0	0	0	0	0	0	0
METHYL IODIDE	1	0	27	0	230	350	607	607
METHYL ISOCYANATE	1	0	0	0	0	0	0	0
METHYLENE BROMIDE	1	0	0	0	0	0	0	0
O-DINITROBENZENE	1	0	0	0	0	0	0	0
OXY-ALKYLATED ALCOHOL	1	5	0	0	0	0	5	5
P-PHENYLENEDIAMINE	1	0	0	0	0	0	0	0
PHENYL MIXTURE	1	0	0	0	0	11,525	11,525	11,525
PHOSPHORUS (YELLOW OR WHITE)	1	0	0	0	0	0	0	0
SACCHARIN (MANUFACTURING)	1	7	840	0	0	0	847	847
TITANIUM TETRACHLORIDE	1	0	0	0	0	0	0	0
ZINC (FUME OR DUST)	1	0	0	0	0	0	0	0
1,3-DICHLOROBENZENE	1	0	0	860	570	0	1,430	1,430
1,3-DICHLOROPROPYLENE	1	0	0	0	0	0	0	0
1,4-DICHLOROBENZENE	1	0	0	0	4	0	4	4
2-NITROPROPANE	1	0	0	0	12,180	0	12,180	12,180
2,4-DIAMINOANISOLE	1	0	0	0	0	0	0	0
2,4-DINITROTOLUENE	1	0	0	0	0	300	300	300
2,6-SYLIDINE	1	0	0	0	0	0	0	0
4-NITROPHENOL	1	0	0	0	1	0	5	5
5-NITRO-O-ANISIDINE	1	5	0	0	0	0	5	5

The TRI database contains a detailed compilation of self-reported, facility-specific chemical releases. The top reporting facilities for this sector are listed below (Exhibit 18). Facilities that have reported only the SIC codes covered under this notebook appear on the first list. Exhibit 19 contains additional facilities that have reported the SIC code covered within this report, and one or more SIC codes that are not within the scope of this notebook. Therefore, the second list includes facilities that conduct multiple operations -- some that are under the scope of this notebook, and some that are not. Currently, the facility-level data do not allow pollutant releases to be broken apart by industrial process.

Exhibit 18: Top 10 TRI Releasing Organic Chemical Manufacturing Facilities[b]

Rank	Facility	Total TRI Releases in Pounds
1	Du Pont Victoria Plant - Victoria, TX	22,471,672
2	BP Chemicals Inc. Green Lake - Port Lavaca, TX	20,650,979
3	Zeneca Specialties Mount Pleasant Plant - Mt. Pleasant, TN	13,429,259
4	Hoechst-Celanese Chemical Group Inc. Clear Lake Plant - Pasadena, TX	10,354,443
5	Du Pont Sabine River Works - Orange, TX	9,731,302
6	Merichem Co. - Houston, TX	3,832,980
7	Hoechst-Celanese Chemical Group Inc. - Bay City, TX	3,454,971
8	Union Carbide C & P CO. Institute WV Plant Ops. - Institute, WV	3,082,932
9	Aqualon - Hopewell, VA	3,007,010
10	Aristech Chemical Corp. - Haverhill, OH	2,858,009

Source: U.S. EPA, Toxics Release Inventory Database, 1993

[b] Being included on this list does not mean that the release is associated with non-compliance with environmental laws.

Exhibit 19: Top 10 TRI Releasing Facilities Reporting Organic Chemical Manufacturing SIC Codes to TRI[c]			
Rank	**SIC Codes Reported in TRI**	**Facility**	**Total TRI Releases in Pounds**
1	2819, 2869	Cytec Inc. Inc. Fortier Plant - Westwego, LA	120,149,724
2	2869, 2819, 2841, 2879	Monsanto Co. - Alvin, TX	40,517,095
3	2822, 2865, 2869, 2873	Du Pont Beaumont Plant - Beaumont, TX	36,817,348
4	2823, 2821, 2869, 2824	Tennessee Eastman Division - Kingsport, TN	29,339,677
5	2869, 2865, 2819	Sterling Chemicals Inc. - Texas City, TX	24,709,135
6	2869	Du Pont Victoria Plant - Victoria, TX	22,471,672
7	2869	BP Chemicals Inc. Green Lake - Port Lavaca, TX	20,650,979
8	2821, 2869, 2873	BP Chemicals - Lima, OH	20,620,680
9	2812, 2869, 2813	Vulcan Chemicals - Cheyenne, WY	17,406,218
10	2813, 2819, 2869, 2873	Coastal Chemicals Inc. - Cheyenne, WY	15,334,423
Source: U.S. EPA, Toxics Release Inventory Database, 1993.			

[c] Being included on this list does not mean that the release is associated with non-compliance with environmental laws.

IV.B. Summary of Selected Chemicals Released

The brief descriptions provided below were taken from the *1993 Toxics Release Inventory Public Data Release* (EPA, 1994), the Hazardous Substances Data Bank (HSDB), and the Integrated Risk Information System (IRIS), both accessed via TOXNET.[d]

Ammonia[e] (CAS: 7664-41-7)

Toxicity. Anhydrous ammonia is irritating to the skin, eyes, nose, throat, and upper respiratory system.

Ecologically, ammonia is a source of nitrogen (an essential element for aquatic plant growth), and may therefore contribute to eutrophication of standing or slow-moving surface water, particularly in nitrogen-limited waters such as the Chesapeake Bay. In addition, aqueous ammonia is moderately toxic to aquatic organisms.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. Ammonia combines with sulfate ions in the atmosphere and is washed out by rainfall, resulting in rapid return of ammonia to the soil and surface waters.

Ammonia is a central compound in the environmental cycling of nitrogen. Ammonia in lakes, rivers, and streams is converted to nitrate.

Physical Properties. Ammonia is a corrosive and severely irritating gas with a pungent odor.

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[d] TOXNET is a computer system run by the National Library of Medicine that includes a number of toxicological databases managed by EPA, National Cancer Institute, and the National Institute for Occupational Safety and Health. For more information on TOXNET, contact the TOXNET help line at 800-231-3766. Databases included in TOXNET are: CCRIS (Chemical Carcinogenesis Research Information System), DART (Developmental and Reproductive Toxicity Database), DBIR (Directory of Biotechnology Information Resources), EMICBACK (Environmental Mutagen Information Center Backfile), GENE-TOX (Genetic Toxicology), HSDB (Hazardous Substances Data Bank), IRIS (Integrated Risk Information System), RTECS (Registry of Toxic Effects of Chemical Substances), and TRI (Toxic Chemical Release Inventory). HSDB contains chemical-specific information on manufacturing and use, chemical and physical properties, safety and handling, toxicity and biomedical effects, pharmacology, environmental fate and exposure potential, exposure standards and regulations, monitoring and analysis methods, and additional references.

[e] The reporting standards for ammonia were changed in 1995. Ammonium sulfate is deleted from the list and threshold and release determinations for aqueous ammonia are limited to 10 percent of the total ammonia present in solution. This change will reduce the amount of ammonia reported to TRI. Complete details of the revisions can be found in 40 CFR Part 372.

<u>*Nitric Acid*</u> (CAS: 7697-37-2)

Toxicity. The toxicity of nitric acid is related to its potent corrosivity as an acid, with ulceration of all membranes and tissues with which it comes in contact. Concentrated nitric acid causes immediate opacification and blindness of the cornea when it comes in contact with the eye. Inhalation of concentrated nitric acid causes severe, sometimes fatal, corrosion of the respiratory tract. Ingestion of nitric acid leads to gastric hemorrhaging, nausea, and vomiting. Circulatory shock is often the immediate cause of death due to nitric acid exposure. Damage to the respiratory system may be delayed for months, and even years. Populations at increased risk from nitric acid exposure include people with pre-existing skin, eye, or cardiopulmonary disorders.

Ecologically, gaseous nitric acid is a component of acid rain. Acid rain causes serious and cumulative damage to surface waters and aquatic and terrestrial organisms by decreasing water and soil pH levels. Nitric acid in rainwater acts as a topical source of nitrogen, preventing "hardening off" of evergreen foliage and increasing frost damage to perennial plants in temperate regions. Nitric acid also acts as an available nitrogen source in surface water, stimulating plankton and aquatic weed growth.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. Nitric acid is mainly transported in the atmosphere as nitric acid vapors and in water as dissociated nitrate and hydrogen ions. In soil, nitric acid reacts with minerals such as calcium and magnesium, becoming neutralized, and at the same time decreasing soil "buffering capacity" against changes in pH levels.

Nitric acid leaches readily to groundwater, where it decreases the pH of the affected groundwater. In the winter, gaseous nitric acid is incorporated into snow, causing surges of acid during spring snow melt. Forested areas are strong sinks for nitric acid, incorporating the nitrate ions into plant tissues.

<u>*Methanol*</u> *(CAS: 67-56-1)*

Toxicity. Methanol is readily absorbed from the gastrointestinal tract and the respiratory tract, and is toxic to humans in moderate to high doses. In the body, methanol is converted into formaldehyde and formic acid. Methanol is excreted as formic acid. Observed toxic effects at high dose levels generally include central nervous system damage and blindness. Long-term exposure to high levels of methanol via inhalation cause liver and blood damage in animals.

Ecologically, methanol is expected to have low toxicity to aquatic organisms. Concentrations lethal to half the organisms of a test population are expected to exceed one mg methanol per liter water. Methanol is not likely to persist in water or to bioaccumulate in aquatic organisms.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. Liquid methanol is likely to evaporate when left exposed. Methanol reacts in air to produce formaldehyde which contributes to the formation of air pollutants. In the atmosphere it can react with other atmospheric chemicals or be washed out by rain. Methanol is readily degraded by microorganisms in soils and surface waters.

Physical Properties. Methanol is highly flammable

<u>*Ethylene Glycol*</u> (CAS: 74-85-1)

Sources. Ethylene glycol is used as an antifreeze, heat transfer agent and solvent in industrial organic chemical facilities. The large quantity of ethylene glycol released is due to its ubiquitous use as an antifreeze and because in 1993 it had the 29th largest chemical production volume in the United States (*Chemical and Engineering News*). While the largest volume is released through underground injection, a substantial release also occurs from air point sources.

Toxicity. Long-term inhalation exposure to low levels of ethylene glycol may cause throat irritation, mild headache and backache. Exposure to higher concentrations may lead to unconsciousness. Liquid ethylene glycol is irritating to the eyes and skin.

Toxic effects from ingestion of ethylene glycol include damage to the central nervous system and kidneys, intoxication, conjunctivitis, nausea and vomiting, abdominal pain, weakness, low blood oxygen, tremors, convulsions, respiratory failure, and coma. Renal failure due to ethylene glycol poisoning can lead to death.

Environmental Fate. Ethylene glycol readily biodegrades in water. No data are available that report its fate in soils; however, biodegradation is probably the dominant removal mechanism. Should ethylene glycol leach into the groundwater, biodegradation may occur.

Ethylene glycol in water is not expected to bioconcentrate in aquatic organisms, adsorb to sediments or volatilize. Atmospheric ethylene glycol degrades rapidly in the presence of hydroxyl radicals.

Acetone (CAS: 67-64-1)

Toxicity. Acetone is irritating to the eyes, nose, and throat. Symptoms of exposure to large quantities of acetone may include headache, unsteadiness, confusion, lassitude, drowsiness, vomiting, and respiratory depression.

Reactions of acetone (see environmental fate) in the lower atmosphere contribute to the formation of ground-level ozone. Ozone (a major component of urban smog) can affect the respiratory system, especially in sensitive individuals such as asthmatics or allergy sufferers.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. If released into water, acetone will be degraded by microorganisms or will evaporate into the atmosphere. Degradation by microorganisms will be the primary removal mechanism.

Acetone is highly volatile, and once it reaches the troposphere (lower atmosphere), it will react with other gases, contributing to the formation of ground-level ozone and other air pollutants. EPA is reevaluating acetone's reactivity in the lower atmosphere to determine whether this contribution is significant.

Physical Properties. Acetone is a volatile and flammable organic chemical.

IV.C. Other Data Sources

The toxic chemical release data obtained from TRI captures the vast majority of facilities in the organic chemicals industry. It also allows for a comparison across years and industry sectors. Reported chemicals are limited however to the 316 reported chemicals. Most of the hydrocarbon emissions from organic chemical facilities are not captured by TRI.[1] The EPA Office of Air Quality Planning and Standards has compiled air pollutant emission factors for determining the total air emissions of priority pollutants (e.g., total hydrocarbons, SO_x, NO_x, CO, particulates, etc.) from many chemical manufacturing sources.[2]

The EPA Office of Air's Aerometric Information Retrieval System (AIRS) contains a wide range of information related to stationary sources of air pollution, including the emissions of a number of air pollutants which may be of concern within a particular industry. With the exception of volatile organic compounds (VOCs), there is little overlap with the TRI chemicals reported above. Exhibit 20 summarizes annual releases of carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter of 10 microns or less (PM10), total particulate (PT), sulfur dioxide (SO_2), and volatile organic compounds (VOCs).

Exhibit 20: Pollutant Releases (short tons/year)

Industry Sector	CO	NO_2	PM_{10}	PT	SO_2	VOC
Metal Mining	5,391	28,583	39,359	140,052	84,222	1,283
Nonmetal Mining	4,525	28,804	59,305	167,948	24,129	1,736
Lumber and Wood Production	123,756	42,658	14,135	63,761	9,419	41,423
Furniture and Fixtures	2,069	2,981	2,165	3,178	1,606	59,426
Pulp and Paper	624,291	394,448	35,579	113,571	541,002	96,875
Printing	8,463	4,915	399	1,031	1,728	101,537
Inorganic Chemicals	166,147	103,575	4,107	39,062	182,189	52,091
Organic Chemicals	**146,947**	**236,826**	**26,493**	**44,860**	**132,459**	**201,888**
Petroleum Refining	419,311	380,641	18,787	36,877	648,155	369,058
Rubber and Misc. Plastics	2,090	11,914	2,407	5,355	29,364	140,741
Stone, Clay and Concrete	58,043	338,482	74,623	171,853	339,216	30,262
Iron and Steel	1,518,642	138,985	42,368	83,017	238,268	82,292
Nonferrous Metals	448,758	55,658	20,074	22,490	373,007	27,375
Fabricated Metals	3,851	16,424	1,185	3,136	4,019	102,186
Computer and Office Equipment	24	0	0	0	0	0
Electronics and Other Electrical Equipment and Components	367	1,129	207	293	453	4,854
Motor Vehicles, Bodies, Parts and Accessories	35,303	23,725	2,406	12,853	25,462	101,275
Dry Cleaning	101	179	3	28	152	7,310

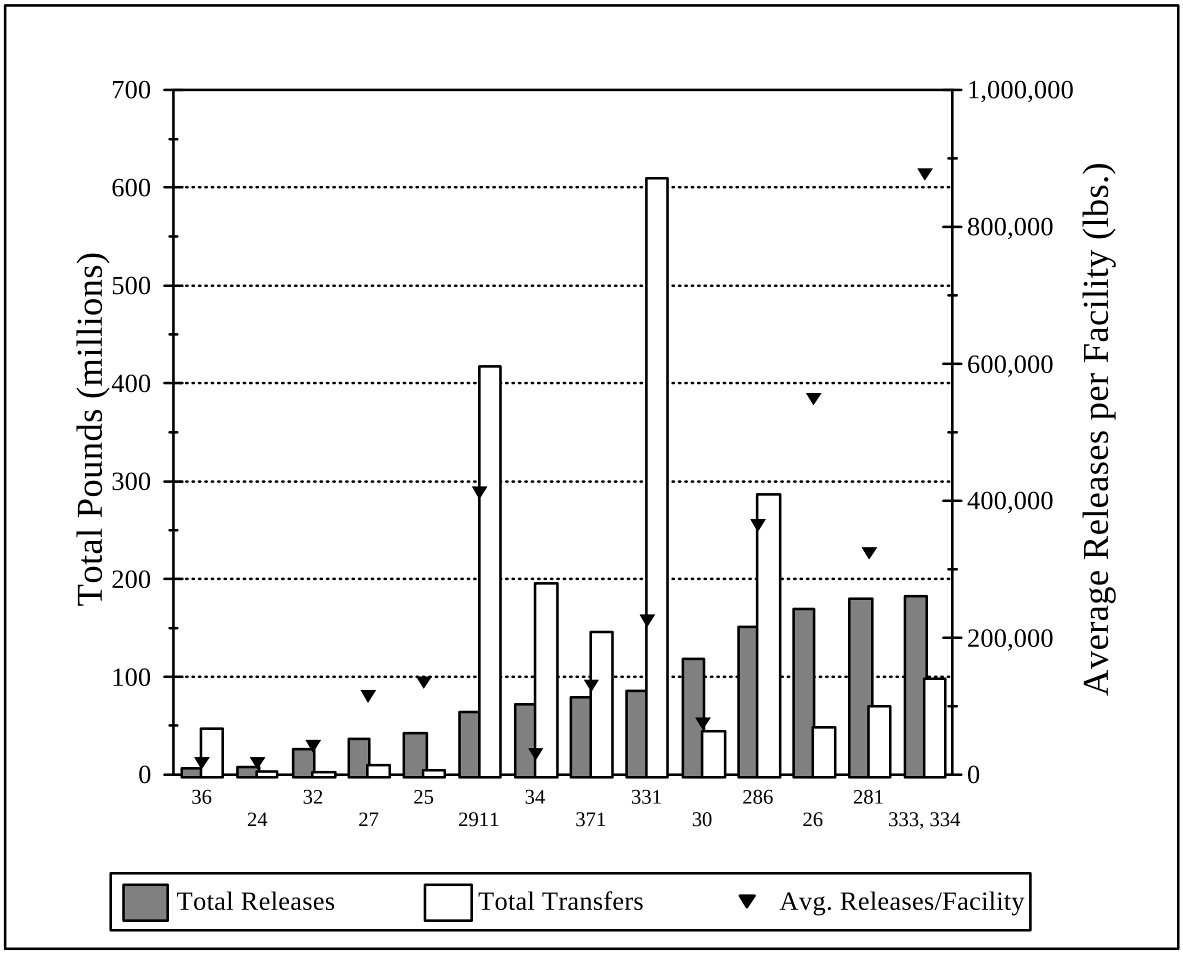
Source: U.S. EPA Office of Air and Radiation, AIRS Database, May 1995.

IV.D. Comparison of Toxic Release Inventory Between Selected Industries

The following information is presented as a comparison of pollutant release and transfer data across industrial categories. It is provided to give a general sense as to the relative scale of releases and transfers within each sector profiled under this project. Please note that the following figure and table do not contain releases and transfers for industrial categories that are not included in this project, and thus cannot be used to draw conclusions regarding the total release and transfer amounts that are reported to TRI. Similar information is available within the annual TRI Public Data Release Book.

Exhibit 21 is a graphical representation of a summary of the 1993 TRI data for the organic chemical industry and the other sectors profiled in separate notebooks. The bar graph presents the total TRI releases and total transfers on the left axis and the triangle points show the average releases per facility on the right axis. Industry sectors are presented in the order of increasing total TRI releases. The graph is based on the data shown in Exhibit 22 and is meant to facilitate comparisons between the relative amounts of releases, transfers, and releases per facility both within and between these sectors. The reader should note, however, that differences in the proportion of facilities captured by TRI exist between industry sectors. This can be a factor of poor SIC matching and relative differences in the number of facilities reporting to TRI from the various sectors. In the case of the organic chemical industry, the 1993 TRI data presented here covers 417 facilities. Only those facilities listing SIC Codes falling within SIC 286 were used.

Exhibit 21: Summary of 1993 TRI Data:
Releases and Transfers by Industry



SIC Range	Industry Sector	SIC Range	Industry Sector	SIC Range	Industry Sector
36	Electronic Equipment and Components	2911	Petroleum Refining	286	Organic Chemical Mfg.
24	Lumber and Wood Products	34	Fabricated Metals	26	Pulp and Paper
32	Stone, Clay, and Concrete	371	Motor Vehicles, Bodies, Parts, and Accessories	281	Inorganic Chemical Mfg.
27	Printing	331	Iron and Steel	333,334	Nonferrous Metals
25	Wood Furniture and Fixtures	30	Rubber and Misc. Plastics		

Exhibit 22: Toxics Release Inventory Data for Selected Industries

Industry Sector	SIC Range	# TRI Facilities	1993 TRI Releases		1993 TRI Transfers		Total Releases + Transfers (million lbs.)	Average Releases + Transfers per Facility (pounds)
			Total Releases (million lbs.)	Average Releases per Facility (pounds)	Total Transfers (million lbs.)	Average Transfers per Facility (pounds)		
Stone, Clay, and Concrete	32	634	26.6	42,000	2.2	4,000	28.8	46,000
Lumber and Wood Products	24	491	8.4	17,000	3.5	7,000	11.9	24,000
Furniture and Fixtures	25	313	42.2	135,000	4.2	13,000	46.4	148,000
Printing	2711-2789	318	36.5	115,000	10.2	32,000	46.7	147,000
Electronic Equip. and Components	36	406	6.7	17,000	47.1	116,000	53.7	133,000
Rubber and Misc. Plastics	30	1,579	118.4	75,000	45	29,000	163.4	104,000
Motor Vehicles, Bodies, Parts, and Accessories	371	609	79.3	130,000	145.5	239,000	224.8	369,000
Pulp and Paper	2611-2631	309	169.7	549,000	48.4	157,000	218.1	706,000
Inorganic Chem. Mfg.	2812-2819	555	179.6	324,000	70	126,000	249.7	450,000
Petroleum Refining	2911	156	64.3	412,000	417.5	2,676,000	481.9	3,088,000
Fabricated Metals	34	2,363	72	30,000	195.7	83,000	267.7	123,000
Iron and Steel	331	381	85.8	225,000	609.5	1,600,000	695.3	1,825,000
Nonferrous Metals	333, 334	208	182.5	877,000	98.2	472,000	280.7	1,349,000
Organic Chemical Mfg.	**2861-2869**	**417**	**151.6**	**364,000**	**286.7**	**688,000**	**438.4**	**1,052,000**
Metal Mining	10	Industry sector not subject to TRI reporting.						
Nonmetal Mining	14	Industry sector not subject to TRI reporting.						
Dry Cleaning	7216	Industry sector not subject to TRI reporting.						

Source: U.S. EPA, Toxics Release Inventory Database, 1993.

V. POLLUTION PREVENTION OPPORTUNITIES

The best way to reduce pollution is to prevent it in the first place. Some companies have creatively implemented pollution prevention techniques that improve efficiency and increase profits while at the same time minimizing environmental impacts. This can be done in many ways such as reducing material inputs, re-engineering processes to reuse by-products, improving management practices, and substituting benign chemicals for toxic ones. Some smaller facilities are able to actually get below regulatory thresholds just by reducing pollutant releases through aggressive pollution prevention policies.

In order to encourage these approaches, this section provides both general and company-specific descriptions of some pollution prevention advances that have been implemented within the organic chemical industry. While the list is not exhaustive, it does provide core information that can be used as the starting point for facilities interested in beginning their own pollution prevention projects. When possible, this section provides information from real activities that can, or are being implemented by this sector -- including a discussion of associated costs, time frames, and expected rates of return. This section provides summary information from activities that may be, or are being implemented by this sector. When possible, information is provided that gives the context in which the technique can be effectively used. Please note that the activities described in this section do not necessarily apply to all facilities that fall within this sector. Facility-specific conditions must be carefully considered when pollution prevention options are evaluated, and the full impacts of the change must examine how each option affects air, land and water pollutant releases.

The leaders in the organic chemical industry, similar to those in the chemical industry as a whole, have been promoting pollution prevention through various means. The most visible of these efforts is the Responsible Care® initiative of the Chemical Manufacturer's Association (CMA). Responsible Care is mandatory for CMA members who must commit to act as stewards for products through use and ultimate reuse or disposal. One of the guiding principles of this initiative is the inclusion of waste and release prevention objectives in research and in design of new or modified facilities, processes and products. The Synthetic Organic Chemical Manufactures Association (SOCMA) also requires its members to implement the Responsible Care® Guiding Principles as a condition of membership. SOCMA is instituting the Responsible Care® management practice codes on a phased-in basis to assist its approximately 110-non CMA members, which are primarily small and batch chemical manufacturers, in successfully implementing their programs.

Using pollution prevention techniques which prevent the release or generation of pollution in the first place have several advantages over end-of-pipe waste treatment technologies. The table below lists the direct and indirect benefits that could result.

Exhibit 23: Pollution Prevention Activities Can Reduce Costs

Direct Benefits
- Reduced waste treatment costs
  - Reduced capital and operating costs for waste treatment facilities
  - Reduced off-site treatment and disposal costs
- Reduced manufacturing costs due to improved yields
- Income or savings from sale or reuse of wastes
- Reduced environmental compliance costs (e.g., fines, shutdowns)
- Reduced or eliminated inventories or spills
- Reduced secondary emissions from waste treatment facilities
- Retained sales (production threatened by poor environmental performance or sales)

Indirect Benefits
- Reduced likelihood of future costs from:
  - Remediation
  - Legal liabilities
  - Complying with future regulations
- Use of emission offsets (internal and external)
- Improved community relations
- Increase environmental awareness by plant personnel and management
- Reduced societal costs
- Improved public health

Source: Chemical Manufacturer's Association *Designing Pollution Prevention into the Process*

These incentives may encourage organic chemical manufacturers to undertake pollution prevention activities voluntarily, but a number of barriers still exist in achieving widespread adoption of pollution prevention. The U.S. Office of Technology Assessment has identified and characterized a number of these barriers in its report titled *Industry, Technology, and the Environment*.

Pollution prevention can be carried out at any stage of the development of a process. In general, changes made at the research and development stage will have the greatest impact; however, changes in the process design and operating practices can also yield significant results.

In the research and development stage, all possible reaction pathways for producing the desired product can be examined. These can then be evaluated in light of yield, undesirable by-products, and their health and environmental impacts. The area of “green synthesis” is the focus of considerable research funded jointly by the Agency and by the National

Science Foundation. Several alternative syntheses have already been developed that could reduce wastes. For example, Joseph M. Desimone of the University of North Carolina, Chapel Hill, has used supercritical carbon dioxide as a medium for carrying out dispersion polymerizations. He uses a specially engineered free-radical initiator to start the reaction and a polymeric stabilizer to affect the polymerization of methyl methacrylate. Because the carbon dioxide can easily be separated from the reaction mixture, this reaction offers the possibility of reduced hazardous waste generation, particularly of aqueous streams contaminated with residual monomer and initiator.

Because of the large investment in current technology, and the lifetime of capital equipment, pollution prevention at the earliest stages is unlikely unless a company undertakes the design of a new production line or facility. There are, however, more numerous pollution prevention opportunities that can be realized by modifying current processes and equipment.

Exhibit 24: Process/Product Modifications Create Pollution Prevention Opportunities

Area	Potential Problem	Possible Approach
By-products Co-products		
Quantity and Quality	▪ Process inefficiencies result in the generation of undesired by-products and co-products. Inefficiencies will require larger volumes of raw materials and result in additional secondary products. Inefficiencies can also increase fugitive emissions and wastes generated through material handling.	▪ Increase product yield to reduce by-product and co-product generation and raw material requirements.
Uses and Outlets	▪ By-products and co-products are not fully utilized, generating material or waste that must be managed.	▪ Identify uses and develop a sales outlet. Collect information necessary to firm up a purchase commitment such as minimum quality criteria, maximum impurity levels that can be tolerated, and performance criteria.
Catalysts		
Composition	▪ The presence of heavy metals in catalysts can result in contaminated process wastewater from catalyst handling and separation. These wastes may require special treatment and disposal procedures or facilities. Heavy metals can be inhibitory or toxic to biological wastewater treatment units. Sludge from wastewater treatment units may be classified as hazardous due to heavy metals content. Heavy metals generally exhibit low toxicity thresholds in aquatic environments and may bioaccumulate.	▪ Catalysts comprised of noble metals, because of their cost, are generally recycled by both onsite and offsite reclaimers.
Preparation and Handling	▪ Emissions or effluents are generated with catalyst activation or regeneration.	▪ Obtain catalyst in the active form. ▪ Provide insitu activation with appropriate processing/activation facilities.
	▪ Catalyst attrition and carryover into product requires de-ashing facilities which are a likely source of wastewater and solid waste.	▪ Develop a more robust catalyst or support.

Exhibit 24 (cont.): Process/Product Modifications Create Pollution Prevention Opportunities

Area	Potential Problem	Possible Approach
Catalysts (cont.)		
Preparation and Handling (cont.)	▪ Catalyst is spent and needs to be replaced.	▪ In situ regeneration eliminates unloading/loading emissions and effluents versus offsite regeneration or disposal.
	▪ Pyrophoric catalyst needs to be kept wet, resulting in liquid contaminated with metals.	▪ Use a nonpryrophoric catalyst. Minimize amount of water required to handle and store safely.
	▪ Short catalyst life.	▪ Study and identify catalyst deactivitation mechanisms. Avoid conditions which promote thermal or chemical deactivation. By extending catalyst life, emissions and effluents associated with catalyst handling and regeneration can be reduced.
Effectiveness	▪ Catalyzed reaction has by-product formation, incomplete conversion and less-than-perfect yield.	▪ Reduce catalyst consumption with a more active form. A higher concentration of active ingredient or increased surface area can reduce catalyst loadings. ▪ Use a more selective catalyst which will reduce the yield of undesired by-products. ▪ Improve reactor mixing/contacting to increase catalyst effectiveness.
	▪ Catalyzed reaction has by-product formation, incomplete conversion and less-than perfect yield.	▪ Develop a thorough understanding of reaction to allow optimization of reactor design. Include in the optimization, catalyst consumption and by-product yield.
Intermediate Products		
Quantity and Quality	▪ Intermediate reaction products or chemical species, including trace levels of toxic constituents, may contribute to process waste under both normal and upset conditions.	▪ Modify reaction sequence to reduce amount or change composition of intermediates.
	▪ Intermediates may contain toxic constituents or have characteristics that are harmful to the environment.	▪ Modify reaction sequence to change intermediate properties. ▪ Use equipment design and process control to reduce releases.

Exhibit 24 (cont.): Process/Product Modifications Create Pollution Prevention Opportunities		
Area	**Potential Problem**	**Possible Approach**
Process Conditions/ Configuration *Temperature*	▪ High heat exchange tube temperatures cause thermal cracking/decomposition of many chemicals. These lower molecular weight by-products are a source of “light ends” and fugitive emissions. High localized temperature gives rise to polymerization of reactive monomers, resulting in “heavies” or “tars.” such materials can foul heat exchange equipment or plug fixed-bed reactors, thereby requiring costly equipment cleaning and production outage.	▪ Select operating temperatures at or near ambient temperature whenever possible. ▪ Use lower pressure steam to lower temperatures. ▪ Use intermediate exchangers to avoid contact with furnace tubes and walls. ▪ Use staged heating to minimize product degradation and unwanted side reactions. ▪ Use superheat of high-pressure steam in place of furnace. ▪ Monitor exchanger fouling to correlate process conditions which increase fouling, avoid conditions which rapidly foul exchangers. ▪ Use online tube cleaning technologies to keep tube surfaces clean to increase heat transfer. ▪ Use scraped wall exchangers in viscous service. ▪ Use falling film reboiler, pumped recirculation reboiler or high-flux tubes.
	▪ Higher operating temperatures imply “heat input” usually via combustion which generates emissions. ▪ Heat sources such as furnaces and boilers are a source of combustion emissions. ▪ Vapor pressure increases with increasing temperature. Loading/ unloading, tankage and fugitive emissions generally increase with increasing vapor pressure.	▪ Explore heat integration opportunities (e.g., use waste heat to preheat materials and reduce the amount of combustion required.) ▪ Use thermocompressor to upgrade low-pressure steam to avoid the need for additional boilers and furnaces. ▪ If possible, cool materials before sending to storage. ▪ Use hot process streams to reheat feeds.

Exhibit 24 (cont.): Process/Product Modifications Create Pollution Prevention Opportunities		
Area	**Potential Problem**	**Possible Approach**
Process Conditions/ Configuration (cont.) *Temperature (cont.)*		■ Add vent condensers to recover vapors in storage tanks or process. ■ Add closed dome loading with vapor recovery condensers.
	■ Water solubility of most chemicals increases with increasing temperature.	■ Use lower temperature (vacuum processing).
Pressure	■ Fugitive emissions from equipment.	■ Equipment operating in vacuum service is not a source of fugitives; however, leaks into the process require control when system is degassed.
	■ Seal leakage potential due to pressure differential.	■ Minimize operating pressure.
	■ Gas solubility increases with higher pressures.	■ Determine whether gases can be recovered, compressed, and reused or require controls.
Corrosive Environment	■ Material contamination occurs from corrosion products. Equipment failures result in spills, leaks and increased maintenance costs.	■ Improve metallurgy or provide coating or lining. ■ Neutralize corrosivity of materials contacting equipment. ■ Use corrosion inhibitors.
	■ Increased waste generation due to addition of corrosion inhibitors or neutralization.	■ Improve metallurgy or provide coating or lining or operate in a less corrosive environment.
Batch vs. Continuous Operations	■ Vent gas lost during batch fill.	■Equalize reactor and storage tank vent lines. ■Recover vapors through condenser, adsorber, etc.
	■ Waste generated by cleaning/purging of process equipment between production batches.	■ Use materials with low viscosity. Minimize equipment roughness.

Exhibit 24 (cont.): Process/Product Modifications Create Pollution Prevention Opportunities

Area	Potential Problem	Possible Approach
Process Conditions/ Configuration (cont.)		
Batch vs. Continuous Operations (cont.)		■ Optimize product manufacturing sequence to minimize washing operations and cross-contamination of subsequent batches.
	■ Process inefficiencies lower yield and increase emissions.	■ Sequence addition of reactants and reagents to optimize yields and lower emissions.
	■ Continuous process fugitive emissions and waste increase over time due to equipment failure through a lack of maintenance between turnarounds.	■Design facility to readily allow maintenance so as to avoid unexpected equipment failure and resultant release.
Process Operation/Design	■ Numerous processing steps create wastes and opportunities for errors.	■ Keep it simple. Make sure all operations are necessary. More operations and complexity only tend to increase potential emission and waste sources.
	■ Nonreactant materials (solvents, absorbants, etc.) create wastes. Each chemical (including water) employed within the process introduces additional potential waste sources; the composition of generated wastes also tends to become more complex.	■ Evaluate unit operation or technologies (e.g., separation) that do not require the addition of solvents or other nonreactant chemicals.
	■ High conversion with low yield results in wastes.	■ Recycle operations generally improve overall use of raw materials and chemicals, thereby both increasing the yield of desired products while at the same time reducing the generation of wastes. A case-in-point is to operate at a lower conversion per reaction cycle by reducing catalyst consumption, temperature, or residence time. Many times, this can result in a higher selectivity to desired products. The net effect upon recycle of unreacted reagents is an increase in product yield, while at the same time reducing the quantities of spent catalyst and less desirable by-products.

Exhibit 24 (cont.): Process/Product Modifications Create Pollution Prevention Opportunities

Area	Potential Problem	Possible Approach
Process Conditions/ Configuration (cont.)		
Process Operation/Design	▪ Non-regenerative treatment systems result in increased waste versus regenerative systems.	▪ Regenerative fixed bed treating or desiccant operation (e.g., aluminum oxide, silica, activated carbon, molecular sieves, etc.) will generate less quantities of solid or liquid waste than nonregenerative units (e.g., calcium chloride or activated clay). With regenerative units though, emissions during bed activation and regeneration can be significant. Further, side reactions during activation/regeneration can give rise to problematic pollutants.
Product		
Process Chemistry	▪ Insufficient R&D into alternative reaction pathways may miss pollution opportunities such as waste reduction or eliminating a hazardous constituent.	▪ R&D during process conception and laboratory studies should thoroughly investigate alternatives in process chemistry that affect pollution prevention.
Product Formulation	▪ Product based on end-use performance may have undesirable environmental impacts or use raw materials or components that generate excessive or hazardous wastes.	▪ Reformulate products by substituting different material or using a mixture of individual chemicals that meet end-use performance specifications.
Raw Materials		
Purity	▪ Impurities may produce unwanted by-products and waste. Toxic impurities, even in trace amounts, can make a waste hazardous and therefore subject to strict and costly regulation.	▪ Use higher purity materials. ▪ Purify materials before use and reuse if practical. ▪ Use inhibitors to prevent side reactions.
	▪ Excessive impurities may require more processing and equipment to meet product specifications, increasing costs and potential for fugitive emissions, leaks, and spills.	▪ Achieve balance between feed purity, processing steps, product quality and waste generation.
	▪ Specifying a purity greater than needed by the process increases costs and can result in more waste generation by the supplier.	▪ Specify a purity no greater than what the process needs.

Exhibit 24 (cont.): Process/Product Modifications Create Pollution Prevention Opportunities		
Area	**Potential Problem**	**Possible Approach**
Raw Materials (cont.) *Purity (cont.)*	▪ Impurities in clean air can increase inert purges.	▪Use pure oxygen.
	▪ Impurities may poison catalyst prematurely resulting in increased wastes due to yield loss and more frequent catalyst replacement.	▪Install guard beds to protect catalysts.
Vapor Pressure	▪ Higher vapor pressures increase fugitive emissions in material handling and storage.	▪ Use material with lower vapor pressure.
	▪ High vapor pressure with low odor threshold materials can cause nuisance odors.	▪ Use materials with lower vapor pressure and higher odor threshold.
Water Solubility	▪ Toxic or nonbiodegradable materials that are water soluble may affect wastewater treatment operation, efficiency, and cost.	▪ Use less toxic or more biodegradable materials.
	▪ Higher solubility may increase potential for surface and groundwater contamination and may require more careful spill prevention, containment, and cleanup (SPCC) plans.	▪ Use less soluble materials.
	▪ Higher solubility may increase potential for storm water contamination in open areas.	▪ Use less soluble materials. ▪ Prevent direct contact with storm water by diking or covering areas.
	▪ Process wastewater associated with water washing or hydrocarbon/water phase separation will be impacted by containment solubility in water. Appropriate wastewater treatment will be impacted.	▪ Minimize water usage. ▪ Reuse wash water. ▪ Determine optimum process conditions for phase separation. ▪ Evaluate alternative separation technologies (coalescers, membranes, distillation, etc.)

Exhibit 24 (cont.): Process/Product Modifications Create Pollution Prevention Opportunities

Area	Potential Problem	Possible Approach
Raw Materials (cont.)		
Toxicity	■ Community and worker safety and health concerns result from routine and nonroutine emissions. Emissions sources include vents, equipment leaks, wastewater emissions, emergency pressure relief, etc.	■ Use less toxic materials. ■ Reduce exposure through equipment design and process control. Use systems which are passive for emergency containment of toxic releases.
	■ Surges or higher than normal continuous levels of toxic materials can shock or miss wastewater biological treatment systems resulting in possible fines and possible toxicity in the receiving water.	■ Use less toxic material. ■ Reduce spills, leaks, and upset conditions through equipment and process control. ■ Consider effect of chemicals on biological treatment; provide unit pretreatment or diversion capacity to remove toxicity. ■ Install surge capacity for flow and concentration equalization.
Regulatory	■ Hazardous or toxic materials are stringently regulated. They may require enhanced control and monitoring; increased compliance issues and paperwork for permits and record keeping; stricter control for handling, shipping, and disposal; higher sampling and analytical costs; and increased health and safety costs.	■ Use materials which are less toxic or hazardous. ■ Use better equipment and process design to minimize or control releases; in some cases, meeting certain regulatory criteria will exempt a system from permitting or other regulatory requirements.
Form of Supply	■ Small containers increase shipping frequency which increases chances of material releases and waste residues from shipping containers (including wash waters).	■ Use bulk supply, ship by pipeline, or use “jumbo” drums or sacks. ■ In some cases, product may be shipped out in the same containers the material supply was shipped in without washing.
	■ Nonreturnable containers may increase waste.	■ Use returnable shipping containers or drums.
Handling and Storage	■ Physical state (solid, liquid, gaseous) may raise unique environmental, safety, and health issues with unloading operations and transfer to process equipment.	■ Use equipment and controls appropriate to the type of materials to control releases.

Exhibit 24 (cont.): Process/Product Modifications Create Pollution Prevention Opportunities

Area	Potential Problem	Possible Approach
Raw Materials (cont.)		
Handling and Storage (cont.)	▪ Large inventories can lead to spills, inherent safety issues and material expiration.	▪ Minimize inventory by utilizing just-in-time delivery.
Waste Streams		
Quantity and Quality	▪ Characteristics and sources of waste streams are unknown.	▪ Document sources and quantities of waste streams prior to pollution prevention assessment.
	▪ Wastes are generated as part of the process.	▪ Determine what changes in process conditions would lower waste generation of toxicity.
		▪ Determine if wastes can be recycled back into the process.
Composition	▪ Hazardous or toxic constituents are found in waste streams. Examples are: sulfides, heavy metals, halogenated hydrocarbons, and polynuclear aromatics.	▪ Evaluate whether different process conditions, routes, or reagent chemicals (e.g., solvent catalysts) can be substituted or changed to reduce or eliminate hazardous or toxic compounds.
Properties	▪ Environmental fate and waste properties are not known or understood.	▪ Evaluate waste characteristics using the following type properties: corrosivity, ignitability, reactivity, BTU content (energy recovery), biodegradability, aquatic toxicity, and bioaccumulation potential of the waste and of its degradable products, and whether it is a solid, liquid, or gas.
Disposal	▪ Ability to treat and manage hazardous and toxic waste unknown or limited.	▪ Consider and evaluate all onsite and offsite recycle, reuse, treatment, and disposal options available. Determine availability of facilities to treat or manage wastes generated.

Source: Chemical Manufacturer's Association. *Designing Pollution Prevention into the Process, Research, Development and Engineering*.

Exhibit 25: Modifications to Equipment Can Also Prevent Pollution

Equipment	Potential Environment Problem	Possible Approach: Design Related	Possible Approach: Operational Related
Compressors, blowers, fans	■ Shaft seal leaks, piston rod seal leaks, and vent streams	■ Seal-less designs (diaphragmatic, hermetic or magnetic) ■ Design for low emissions (internal balancing, double inlet, gland eductors) ■ Shaft seal designs (carbon rings, double mechanical seals, buffered seals) ■ Double seal with barrier fluid vented to control device	■ Preventive maintenance program
Concrete pads, floors, sumps	■ Leaks to groundwater	■ Water stops ■ Embedded metal plates ■ Epoxy sealing ■ Other impervious sealing	■ Reduce unnecessary purges, transfers, and sampling ■ Use drip pans where necessary
Controls	■ Shutdowns and start-ups generate waste and releases	■ Improve on-line controls ■ On-line instrumentation ■ Automatic start-up and shutdown ■ On-line vibration analysis ■ Use “consensus” systems (e.g., shutdown trip requires 2 out of 3 affirmative responses)	■ Continuous versus batch ■ Optimize on-line run time ■ Optimize shutdown interlock inspection frequency ■ Identify safety and environment critical instruments and equipment
Distillation	■ Impurities remain in process streams	■ Increase reflux ratio ■ Add section to column ■ Column intervals ■ Change feed tray	■ Change column operating conditions - reflux ratio - feed tray - temperature - pressure - etc.

Exhibit 25 (cont.): Modifications to Equipment Can Also Prevent Pollution

Equipment	Potential Environment Problem	Possible Approach: Design Related	Possible Approach: Operational Related
Distillation (cont.)	■ Impurities remain in process streams (cont.)	■ Insulate to prevent heat loss ■ Preheat column feed ■ Increase vapor line size to lower pressure drop	■ Clean column to reduce fouling
	■ Large amounts of contaminated water condensate from stream stripping	■ Use reboilers or inert gas stripping agents	■ Use higher temperature steam
General manufacturing equipment areas	■ Contaminated rainwater	■ Provide roof over process facilities ■ Segregate process sewer from storm sewer (diking) ■ Hard-pipe process streams to process sewer	■ Return samples to process ■ Monitor stormwater discharge
	■ Contaminated sprinkler and fire water	■ Seal floors ■ Drain to sump ■ Route to waste treatment	
	■ Leaks and emissions during cleaning	■ Design for cleaning ■ Design for minimum rinsing ■ Design for minimum sludge ■ Provide vapor enclosure ■ Drain to process	■ Use drip pans for maintenance activities ■ Rinse to sump ■ Reuse cleaning solutions
Heat exchangers	■ Increased waste due to high localized temperatures	■ Use intermediate exchangers to avoid contact with furnace tubes and walls ■ Use staged heating to minimize product degradation and unwanted side reactions. (waste heat >>low pressure steam >>high pressure steam)	■ Select operating temperatures at or near ambient temperature when-ever possible. These are generally most desirable from a pollution prevention standpoint ■ Use lower pressure steam to lower temperatures

Exhibit 25 (cont.): Modifications to Equipment Can Also Prevent Pollution			
		Possible Approach	
Equipment	Potential Environment Problem	Design Related	Operational Related
Heat exchangers (cont.)	▪ Increased waste due to high localized temperatures (cont.)	▪ Use scraped wall exchangers in viscous service ▪ Using falling film reboiler, piped recirculation reboiler or high-flux tubes ▪ Use lowest pressure steam possible	▪ Monitor exchanger fouling to correlate process conditions which increase fouling, avoid conditions which rapidly foul exchangers ▪ Use on-line tube cleaning techniques to keep tube surfaces clean
	▪ Contaminated materials due to tubes leaking at tube sheets	▪ Use welded tubes or double tube sheets with inert purge. Mount vertically	▪ Monitor for leaks
	▪ Furnace emissions	▪ Use superheat of high-pressure steam in place of a furnace	
Piping	▪ Leaks to groundwater; fugitive emissions	▪ Design equipment layout so as to minimize pipe run length ▪ Eliminate underground piping or design for cathodic protection if necessary to install piping underground ▪ Welded fittings ▪ Reduce number of flanges and valves ▪ All welded pipe ▪ Secondary containment ▪ Spiral-wound gaskets ▪ Use plugs and double valves for open end lines ▪ Change metallurgy ▪ Use lined pipe	▪ Monitor for corrosion and erosion ▪ Paint to prevent external corrosion

Exhibit 25 (cont.): Modifications to Equipment Can Also Prevent Pollution

Equipment	Potential Environment Problem	Possible Approach: Design Related	Possible Approach: Operational Related
Piping (cont.)	▪ Releases when cleaning or purging lines	▪ Use “pigs” for cleaning ▪ Slope to low point drain ▪ Use heat tracing and insulation to prevent freezing ▪ Install equalizer lines	▪ Flush to product storage tank
Pumps	▪ Fugitive emissions from shaft seal leaks	▪ Mechanical seal in lieu of packing ▪ Double mechanical seal with inert barrier fluid ▪ Double machined seal with barrier fluid vented to control device ▪ Seal-less pump (canned motor magnetic drive) ▪ Vertical pump	▪ Seal installation practices ▪ Monitor for leaks
	▪ Fugitive emissions from shaft seal leaks	▪ Use pressure transfer to eliminate pump	
	▪ Residual “heel” of liquid during pump maintenance	▪ Low point drain on pump casing	▪ Flush casing to process sewer for treatment ▪ Increase the mean time between pump failures by: - selecting proper seal material; - good alignment; - reduce pipe-induced stress - Maintaining seal lubrication
	▪ Injection of seal flush fluid into process stream	▪ Use double mechanical seal with inert barrier fluid where practical	
Reactors	▪ Poor conversion or performance due to inadequate mixing	▪ Static mixing ▪ Add baffles ▪ Change impellers	▪ Add ingredients with optimum sequence

Exhibit 25 (cont.): Modifications to Equipment Can Also Prevent Pollution			
		Possible Approach	
Equipment	**Potential Environment Problem**	**Design Related**	**Operational Related**
Reactors (cont.)	▪ Poor conversion (cont.) ▪ Waste by-product formation	▪ Add horsepower ▪ Add distributor ▪ Provide separate reactor for converting recycle streams to usable products	▪ Allow proper head space in reactor to enhance vortex effect ▪ Optimize reaction conditions (temperature, pressure, etc.)
Relief Valve	▪ Leaks ▪ Fugitive emissions ▪ Discharge to environment from over pressure ▪ Frequent relief	▪ Provide upstream rupture disc ▪ Vent to control or recovery device ▪ Pump discharges to suction of pump ▪ Thermal relief to tanks ▪ Avoid discharge to roof areas to prevent contamination of rainwater ▪ Use pilot operated relief valve ▪ Increase margin between design and operating pressure	▪ Monitor for leaks and for control efficiency ▪ Monitor for leaks ▪ Reduce operating pressure ▪ Review system performance
Sampling	▪ Waste generation due to sampling (disposal, containers, leaks, fugitives, etc.)	▪ In-line insitu analyzers ▪ System for return to process ▪ Closed loop ▪ Drain to sump	▪ Reduce number and size of samples required ▪ Sample at the lowest possible temperature ▪ Cool before sampling

Tanks	■ Tank breathing and working losses	■ Cool materials before storage ■ Insulate tanks ■ Vent to control device (flare, condenser, etc.) ■ Vapor balancing ■ Floating roof	■ Optimize storage conditions to reduce losses

Exhibit 25 (cont.): Modifications to Equipment Can Also Prevent Pollution

		Possible Approach	
Equipment	**Potential Environment Problem**	**Design Related**	**Operational Related**
Tanks (cont.)	■ Tank breathing and working losses (cont.) ■ Leak to groundwater ■ Large waste heel	■ Floating roof ■ Higher design pressure ■ All aboveground (situated so bottom can routinely be checked for leaks) ■ Secondary containment ■ Improve corrosion resistance ■ Design for 100% de-inventory	■ Monitor for leaks and corrosion ■ Recycle to process if practical
Vacuum Systems	■ Waste discharge from jets	■ Substitute mechanical vacuum pump ■ Evaluate using process fluid for powering jet	■ Monitor for air leaks ■ Recycle condensate to process
Valves	■ Fugitive emissions from leaks	■ Bellow seals ■ Reduce number where practical ■ Special packing sets	■ Stringent adherence to packing procedures
Vents	■ Release to environment	■ Route to control or recovery device	■ Monitor performance

Source: Chemical Manufacturer's Association. *Designing Pollution Prevention into the Process, Research, Development and Engineering*.

It is critical to emphasize that pollution prevention in the chemical industry is process specific and oftentimes constrained by site-specific considerations. As such, it is difficult to generalize about the relative merits of different pollution prevention strategies. The age, size, and purpose of the plant will influence the choice of the most effective pollution prevention strategy. Commodity chemical manufacturers redesign their processes infrequently so that redesign of the reaction process or equipment is unlikely in the short term. Here operational changes are the most feasible response. Specialty chemical manufacturers are making a greater variety of chemicals and have more process and design flexibility. Incorporating changes at the earlier research and development phases may be possible for them.

Changes in operational practices may yield the most immediate gains with the least investment. For example, the majority of the waste generated by the chemical processing industry is contaminated water: Borden Chemical Company has collected and isolated its waste water in a trench coming from the phenol rail car unloading area and reused the water in resin batches. This eliminated the entire waste stream with a capital investment of $3,000 and annual savings of $1,500 a year in treatment costs. Rhone-Poulenc, in New Brunswick, New Jersey, is now sending all quality control and raw material samples back to be reused in the production process saving $20,000 per year and reducing waste volume by 3,000 pounds.

Another area that can yield significant benefits is improved process control so that less off-specification product is produced (that must be discarded) and the process is run more optimally (fewer by-products). Exxon Chemical Americas of Linden, New Jersey, used continuous process optimization to reduce the generation of acid coke, a process residue, thus saving $340,000 annually in treatment costs. New in-line process controls are under development (a fertile area of research being pursued by the Center for Process Analytic Chemistry at the University of Washington) that may allow better process optimization through tighter process control.

Chemical substitution, particularly of water for non-aqueous solvents, can also prevent pollution. For example, Du Pont at the Chamber Works in New Jersey is using a high-pressure water-jet system to clean polymer reaction vessels. This replaces organic solvent cleaning that annually produced 40,000 pounds of solvent waste. Installing the new cleaning system cost $125,000 but it will save $270,000 annually.

Improved separations design also offers a pollution prevention opportunity since separations account for about 20 percent of energy use in the chemical process industry. In one case, a solvent was replaced by an excess of a reaction component, thus eliminating the need to separate the solvent from the waste stream while reducing separation costs.